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Compliance with Biomedical Waste Sorting Practices and Associated Factors in Hospitals in the Lubao Territory, Lomami Province, DRC: An Analytical Cross-Sectional Study

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ABSTRACT

DESCRIPTION OF THE TOPIC

In the Democratic Republic of the Congo, rural hospitals generate significant amounts of biomedical waste, yet scientific data on its management remain scarce.

However, methods for managing healthcare waste can pose risks of nosocomial infections to humans and environmental pollution if the various stages of the management process are not carried out correctly.

Objective. The objective of this study is to assess the level of compliance with current standards regarding biomedical waste sorting practices in hospitals in the Lubao territory (Lomami Province).

Methods. A cross-sectional analytical study using a mixed-methods approach (quantitative and qualitative) was conducted in six hospitals. Data were collected through direct observation, questionnaires administered to healthcare staff, and semi-structured interviews with hygiene managers.

Results. The data collected reveals generally insufficient compliance with sorting practices. Reported compliance rates ranged from 55% in Tshofa to 40% in Lubao and 25% in Kamana, with an estimated overall average of around 40%. Staff training also showed significant disparities: nearly 79.5% of staff received training in Tshofa, compared to 57.5% in Lubao and 40% in Kamana. However, the case of Tshofa demonstrates that a high level of training and better availability of equipment do not automatically guarantee satisfactory compliance.

Key words: Biomedical waste; waste segregation; healthcare facilities; compliance; staff training; Lubao, Democratic Republic of Congo.

1. INTRODUCTION

Biomedical waste management is a major issue concerning public health, workplace safety, and environmental protection. Diagnostic, treatment, prevention, laboratory, and healthcare activities generate a variety of wastes on a daily basis, a portion of which poses infectious, chemical, pharmaceutical, physical, or radioactive risks. According to the World Health Organization, approximately 85% of the waste generated by healthcare activities is classified as non-hazardous general waste, while about 15% is considered hazardous and requires specific management (WHO, 2024). Poor management of this fraction can expose healthcare professionals, waste collectors, patients, and communities to infections, injuries, and toxic substances, while also contributing to environmental damage (Hossain et al., 2011; Chartier et al., 2014).

Source separation is therefore one of the most critical steps in the waste management chain. It involves separating the different categories of waste at the point of generation using appropriate, labeled containers that are, when required by regulations, color-coded. Proper segregation reduces the mixing of hazardous and non-hazardous waste, facilitates its collection and treatment, improves worker safety, and prevents large volumes of ordinary waste from being unnecessarily subjected to treatment procedures reserved for hazardous waste (Chartier et al., 2014; Windfeld and Brooks, 2015). The literature also emphasizes that worker education and the standardization of sorting practices are essential drivers for improving healthcare waste management (Windfeld and Brooks, 2015).

In resource-constrained countries, particularly in sub-Saharan Africa, however, the implementation of these principles continues to face numerous constraints. The work of Hossain et al. (2011) shows that insufficient investment, a shortage of trained personnel, weak oversight, and the absence or inadequate enforcement of guidelines can compromise waste management from initial collection through final disposal. In Tanzania, Manyele and Anicetus (2006) also demonstrated the importance of organizational structures and training in improving hospital waste management. In Ghana, Adu et al. (2020) highlighted persistent difficulties with source separation and the consistent application of color-coding in several hospitals. These observations are consistent with those reported more recently by Ibrahim et al. (2023) in Ethiopia, where training, the existence of guidelines or posters, and the availability of color-coded bins were significantly associated with waste segregation practices. These results suggest that compliance does not depend on a single factor, but rather on the interplay between skills, equipment, standards, organization, and supervision (Caniato et al., 2015). Similar findings were reported in Cameroon by Manga et al. (2011), confirming that challenges in managing healthcare waste also affect several African healthcare systems.

In the Democratic Republic of the Congo, biomedical waste management falls within the broader framework of environmental protection and public health, notably through Law No. 11/009 of July 9, 2011, on fundamental principles relating to environmental protection, as well as technical guidelines applicable to the health sector (Democratic Republic of Congo, 2011; WHO, 2014). However, the constraints observed in many resource-limited settings—insufficient equipment, limited financial resources, lack of training, inadequate supervision, and organizational difficulties—can also be found in Congolese health facilities. Studies conducted in other African contexts show, in particular, that the availability of equipment does not automatically lead to best practices if procedures are not known, posted, monitored, and regularly evaluated (Abah & Ohimain, 2011; Afesi-Dei et al., 2023).

However, most available data on this issue comes from urban settings or relatively well-documented hospital facilities, while rural areas and small towns remain understudied. The Lubao territory, in Lomami Province, illustrates this lack of local data. Its health facilities carry out daily care activities that generate biomedical waste, yet scientific data assessing the compliance of their sorting practices remain limited. Studying this rural context is therefore of particular interest, as constraints related to supply, supervision, training, and organization may take different forms there than those observed in large hospital centers.

This lack of information limits the ability of health officials and local authorities to objectively assess the gaps between observed practices and current standards, to identify priority constraints, and to effectively direct interventions aimed at capacity building, equipment provision, and supervision. This study thus aims to help fill an empirical gap by producing comparative data on several health facilities within the same region. It adopts a descriptive, analytical, and operational perspective, seeking not only to measure the level of compliance but also to understand the factors that may promote or limit the effective implementation of recommended practices.

This study was therefore undertaken to assess the level of compliance with biomedical waste sorting practices in healthcare facilities in the Lubao region, based on the standards and guidelines outlined in the study protocol. More specifically, it aims to :

- Assess the level of training among staff involved in biomedical waste management;
- Examine the availability and use of sorting equipment;
- Assess the implementation of source separation practices and the color-coding system;
- Compare the observed levels of compliance across the different study areas; and
- Identify the main constraints that may limit compliance with these practices.

The study is based on the hypothesis that the level of compliance with biomedical waste sorting practices remains insufficient in the health facilities studied and that this situation may be linked to a combination of human, material, and organizational factors, including staff training, equipment availability, protocol implementation, and supervision of practices.

2. MATERIALS AND METHODS

2.1. Study Setting

This study was conducted in six hospitals in the Lubao territory, located in Lomami Province in the Democratic Republic of Congo. Geographically, the Lubao territory extends between longitudes 24°30′ and 26°30′ East and latitudes 5° and 6°25′ South. This study area was selected to address the lack of empirical data from rural settings and to provide scientific evidence that accurately reflects the realities on the ground regarding the sorting of biomedical waste.

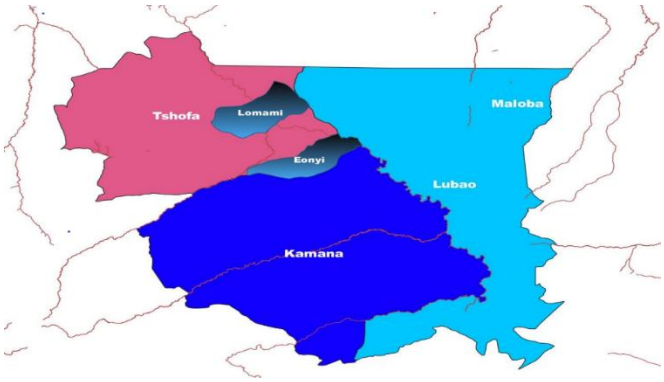


Figure 1: Geographical location of the Lubao Territory in Lomami Province, Democratic Republic of the Congo

2.2. Methods

This research covered the period from May 1, 2025, to January 1, 2026, and adopted a mixed-methods approach, combining quantitative and qualitative methods within a descriptive and analytical study. The quantitative component aims to measure the level of compliance of sorting practices with national and international standards. The qualitative component, meanwhile, allows for an analysis of the behavioral and structural determinants of the management of this waste (Hossain *et al*., 2011). The protocol was carried out in three successive phases: a literature review, a field survey, and, finally, semi-structured interviews supplemented by direct observations.

The sampling was based on a non-probability method using reasoned selection. At the first level, this method was used to select six health facilities. At the second level, it targeted healthcare workers and waste collection staff. The inclusion of healthcare facilities was based on four major criteria: their operational functionality within the Lubao region; the highly critical nature of their services (surgery, maternity, laboratory, minor surgery); the existence of a formalized internal organizational structure; and the presence of a hygiene department or a sanitation manager ensuring a chain of

responsibility. Regarding human actors, the inclusion criterion required direct involvement or proven responsibility for waste management within the selected facilities. The collected data were coded, entered, and cleaned using IBM SPSS Statistics software to ensure data quality prior to analysis. A descriptive statistical analysis was conducted to determine the number of cases, percentages, means, and standard deviations.

Before proceeding with comparative analyses, the conditions for applying statistical tests were rigorously verified. The homogeneity of variances was assessed using Levene's test. For any p-value > 0.05, the variances were considered homogeneous, justifying the use of appropriate parametric tests (Student's t-test or ANOVA). Conversely, for p-values < 0.05, the assumption of homoscedasticity was rejected, leading either to the use of corrections for unequal variances or to the application of nonparametric alternatives when the conditions of normality were not met. The threshold for statistical significance was set at 5% ($p < 0.05$). The results are presented in structured tables and interpreted in light of the study's objectives.

The sample size was determined using Cochran's formula, which is commonly used to estimate a minimum sample size in quantitative studies when the population is large or poorly understood:

$$n_0 = \frac{Z \times p \times (1-p)}{e2}$$

or:

- $N_\circ$ = initial sample size ;
- Z = value from the normal distribution corresponding to the confidence level (1.96 reflecting a 95% confidence level; 2.58 for 99%);
- p = estimated proportion of the phenomenon under study (if unknown, 0.5 is used to obtain the maximum sample size)
- e = 0.05 denotes the acceptable margin of error (for example, 0.05 for 5%) ·

$$n = \frac{(1{,}96)^2 \times 0{,}5 \times (1 - 0{,}5)}{(0{,}05)^2} = \frac{(3{,}84 \times 0{,}25)}{0{,}0025}$$
$$= \frac{0{,}96}{0{,}0025} = 384$$

After applying the correction for the defined population and considering the inclusion criteria, the final size of our sample was set at 104 participants.

2.3. Study Variables

2.3.1 Dependent variables :

Level of compliance with waste sorting and management practices with current standards. This variable can be measured using the following indicators:

- Compliance with source separation
- Adherence to the color-coding system

2.3.2 Dependent and independent variables

Factors likely to influence this compliance:

- Hospital characteristics
- Staff characteristics
- Staff training
- Operational challenges: insufficient financial resources, lack of equipment, low level of involvement by health authorities

3. RESULTS

3.1. Distribution of Respondents by Hospital

Table 1 shows the hospitals included in the investigation into hospital waste sorting and management practices.

Table 1: Distribution of Respondents by Hospital

Region/Hospital	Number of Respondents (n)	Percentage (%)
Tshofa	44	42.3
Lubao	40	38.5
Kamana	20	19.2
Total	104	100.0

Most of respondents are from Tshofa (42.3%), followed by Lubao (38.5%) and Kamana (19.2%). This distribution allows for a comparison of practices across the three areas, while considering that the sample sizes are not equal.

3.2. Staff Training in Biomedical Waste Management

Table 2 presents a comparison of training on hospital waste sorting by health region.

Table 2: Comparison of training received on hospital waste sorting and management practices

Zone/Hospital	Trained n (%)	Not trained n (%)	Total
Tshofa	35 (79.5)	9 (20.5)	44

Lubao	23 (57.5)	17 (42.5)	40
Kamana	8 (40.0)	12 (60.0)	20
Total	66 (63.5)	38 (36.5)	104

Comment: In total, 63.5% of respondents reported having received training. Tshofa has the highest training coverage (79.5%), while Kamana has the lowest (40.0%). This disparity suggests a priority need for capacity building in Kamana.

3.3. Equipment and Compliance with Hospital Waste Sorting by Health Zone

Table 3 presents the availability of equipment and compliance with hospital waste sorting by health region.

Table 3: Availability of sorting equipment by zone/hospital

Zone/Hospital	Equipment Availability	Observed/Reported Use	Assessment
Tshofa	Best	Present but with some errors in use	Relatively favorable
Lubao	Intermediate	Irregular usage	Insufficient
Kamana	Low	Limited availability of suitable equipment	Very insufficient

A gradient in equipment availability is observed, with Tshofa being the best equipped, Lubao in an intermediate situation, and Kamana poorly equipped. However, the presence of equipment does not guarantee its proper use, as illustrated by the persistent errors at Tshofa.

3.4. Compliance with Practices

Table 4 shows the level of compliance with source separation practices

Table 4 : Source Separation Practices

Criteria Evaluated	Observed/Reported Results	Assessment
Separation of hazardous and non-hazardous waste	Inadequate	Non-compliant
Sorting at the point of generation	Rarely performed	Non-compliant
Separation of sharp/piercing waste	Insufficient according to the described practices	Non-compliant
Use of appropriate containers	Inconsistent depending on the area	Partially compliant
Organization of the process after sorting	Inadequate	Non-compliant

Source separation appears to be generally insufficient. The mixing of hazardous and non-hazardous waste, as well as the fact that separation is rarely carried out at the point of generation, are the main weaknesses. This situation compromises the safety of subsequent stages of collection, storage, and disposal.

3.5. Compliance with the color-coding system

Table 5 shows the degree of compliance with the color-coding system

Table 5: Application of the color-coding system

Waste category	Availability/use of containers	Level of Implementation
Infectious waste	Not available or used irregularly	Insufficient
Anatomical waste	Not available or used irregularly	Insufficient
Non-hazardous waste	Irregular use	Insufficient
Recyclable waste	Not available or used irregularly	Insufficient
Pharmaceutical waste	Not available or used irregularly	Insufficient

The color-coding system is not being adequately implemented in the areas studied. The problem stems from a combination of insufficient equipment in certain facilities and improper use of the equipment when it is available. Improvements must therefore address equipment allocation, training, the posting of procedures, and supervision.

3.6. Level of Compliance with Standards

The table below shows the level of compliance with established standards.

Table 6: Level of Compliance with Triage Practices by Area/Hospital

Area/Hospital	Compliance (%)	Non-compliance (%)	Rank
Tshofa	55	45	1st
Lubao	40	60	2nd
Kamana	25	75	3rd

The level of compliance is highest in Tshofa (55%), intermediate in Lubao (40%), and lowest in Kamana (25%). The gradient Tshofa > Lubao > Kamana indicates a significant difference between the areas. Nevertheless, even in Tshofa, nearly half of the criteria are not met.

3.7. Training–Equipment–Compliance

Table 7 presents a comparison of training, equipment, and compliance among the facilities included in the study

Table 7: Comparison of Training, Equipment, and Compliance

Indicator	Tshofa	Lubao	Kamana
Trained staff (%)	79.5	57.5	40.0
Equipment	Improved availability	Intermediate availability	Low availability
Compliance (%)	55	40	25

Overall, the three indicators show a similar trend: Tshofa is the most favorable area and Kamana the least favorable. However, training and equipment alone are not sufficient to explain compliance: Tshofa has the best training coverage and the best equipment, but its compliance remains limited to 55%. Internal organization, supervision, constant access to containers, and adherence to procedures could therefore be factors.

3.8. Perception of Risks

Table 8 presents perceptions of environmental risks and challenges

Table 8: Perception of environmental risks and challenges related to biomedical waste

Indicator	Response	N	%
Link between poor management and climate change	Yes	18	17.3
	No	34	32.7
	Don't know	52	50.0
Link Between Biomedical Waste and Climate Change Worsening	Yes	33	31.7
	No	21	20.1
	Don't know	50	48.1
Willingness to sort if the system is suitable	Yes	45	43.3
	No	20	19.2
	Maybe	39	37.5
Poor management recognized as an environmental problem	Yes	54	51.9
	No	15	14.4
	Maybe	35	33.7

The survey results indicate that awareness of the link between waste management and climate change remains limited: half of the respondents are unsure. However, 51.9% recognize poor waste management as an environmental problem. The willingness to improve recycling is relatively encouraging, as

43.3% answered "yes" and 37.5% answered "maybe," suggesting that an operational system could foster change.

3.9. Factors Associated with Compliance

The table above lists factors potentially associated with compliance with sorting practices

Table 9: Factors Potentially Associated with Compliance in Sorting Practices

Factor	Observed Trend	Interpretation	Statistical analysis
Staff training	Tshofa 79.5% > Lubao 57.5% > Kamana 40.0%	Possible descriptive association with better compliance	Cannot be calculated with aggregated data
Equipment Availability	Tshofa: best > Lubao: moderate > Kamana: low	Possible descriptive association	Cannot be calculated with aggregated data
Organization/procedures	Shortcomings reported in all three areas	Plausible organizational factor	Cannot be calculated
Supervision/audit	Supervision deemed insufficient	Potentially decisive factor	Cannot be calculated
Application of the color code	Insufficient in the areas studied	Contributes to non-compliance	Cannot be calculated

Comment: The data currently available allow only for a descriptive comparison. They do not allow for a valid calculation of a χ^2, p-value, odds ratio, or logistic regression. To identify factors independently associated with compliance, individual data for each respondent are required, and the dependent variable (e.g., compliant/non-compliant) as well as the explanatory variables must be clearly defined.

4. DISCUSSION OF RESULTS

4.1. Staff Training Levels and Implications for Biomedical Waste Management

The results show uneven coverage of staff training across the study areas. The proportion of staff who reported having received training on the sorting and management of biomedical waste reached 79.5% in Tshofa, compared to 57.5% in Lubao and 40% in Kamana. Overall, 66 out of 104 participants, or 63.5%, received training.

These differences highlight significant disparities in access to capacity building. The situation in Kamana appears particularly concerning, as the majority of staff surveyed did not receive any training.

Training, however, is an essential component of safe biomedical waste management. It enables staff to identify different categories of waste, properly separate them, use containers correctly, and understand the risks associated with improper handling (Chartier et al., 2014; WHO, 2018). This relationship between training and practice is also reflected in recent literature. Ibrahim et al. (2023), in a study of 280 professionals in Ethiopia, showed that having received training in waste management was significantly associated with better segregation practices. Similarly, Adu et al. (2020) recommend periodic training on source separation in the hospitals studied in Ghana.

However, the results of this study also indicate that training alone is not sufficient to ensure high compliance. Tshofa, despite having the highest proportion of trained staff, reported a compliance rate of only 55%.

This finding is one of the most interesting lessons from the study. It suggests that acquired knowledge must be accompanied by other favorable conditions, including the actual availability of equipment, the implementation of protocols, regular supervision, and the internal organization of the management chain (Caniato et al., 2015; Hossain et al., 2011). In other words, training appears to be an important factor, but its effect can be negated when the organizational and material context does not allow staff to translate knowledge into consistent, compliant behavior.

It should be noted, however, that in the current version of the analysis, this relationship between training and compliance remains primarily descriptive. A specific statistical analysis would be necessary to determine whether the level of training

is indeed associated with compliance independently of other factors.

4.2. Availability of Equipment and Compliance with Waste Sorting

The results also show significant variation in the availability of equipment. Tshofa is described as the best-equipped area, Lubao as having an intermediate level, while Kamana has little suitable equipment. However, even when equipment is available, its use does not always appear to comply with recommended practices.

In Tshofa, despite better equipment provision, errors in applying the color-coding system persist. In Lubao, equipment is used inconsistently, and sorting remains incomplete. In Kamana, the lack of equipment is associated with a near-total absence of structured sorting.

These results show that the availability of equipment is a necessary but not sufficient condition for compliance. A container of the appropriate color improves waste management only if it is available at the point of generation, properly labeled, used consistently, and integrated into a continuous chain extending from sorting to disposal (WHO, 2018; Windfeld and Brooks, 2015). This observation is consistent with the findings of Ibrahim et al. (2023), who found a significant association between the availability of color-coded bins and the quality of waste separation. In Ghana, however, Afesi-Dei et al. (2023) showed that, even with bins in place and well-trained staff, source separation and the use of color-coding could remain inadequate when institutional monitoring mechanisms did not function properly.

Thus, interventions should avoid being limited solely to the distribution of bins or bags. They should combine equipment, training, posting of procedures, and regular supervision.

4.3. Overall Level of Compliance with Sorting Practices

The overall level of compliance reported in the manuscript remains low. Tshofa reached 55%, Lubao 40%, and Kamana 25%, with an estimated overall average of around 40%. These findings are consistent with a problem already documented in several low- and middle-income countries, where healthcare waste management practices often fall short of recommended standards. Abah and Ohimain (2011), for example, reported in Nigeria that waste management at one facility studied was deemed unsustainable, with a low proportion of workers having received specific training. In Ghana, Afesi-Dei et al. (2023) also found overall noncompliance with guidelines in the facility studied, despite a reported high training coverage rate. However, comparisons must be made with caution, as indicators, populations, and calculation methods differ from one study to another.

These results show that, even in the best-performing facility or area, nearly half of the compliance criteria are not met.

This weakness appears to manifest at several levels of the chain: insufficient separation of hazardous and non-hazardous waste; irregular sorting at the source; incomplete application of the color-coding system; uneven availability of containers; and inadequate organization of storage and disposal.

The comparative table against standards notably highlights the mixing of hazardous and non-hazardous waste, separation that is rarely carried out at the point of generation, and poor adherence to the color-coding system.

These findings are concerning because source separation is critical to the safety of all subsequent stages. When infectious or sharp waste is mixed with ordinary waste, the volume of waste requiring special handling increases, and the risk of accidental exposure multiplies (WHO, 2014; Chartier et al., 2014). The work of Adu et al. (2020) in Ghana illustrates this challenge: the lack of uniform application of the color-coding system and the mixing of different waste categories compromised the effectiveness of subsequent operations. In the present study, comparison with this work reinforces the idea that sorting must be considered a central component of hospital safety rather than merely a collection operation.

However, the manuscript must explicitly describe the method used to obtain the values of 55%, 40%, and 25%. Without a precise definition of the score and compliance criteria, these percentages remain difficult to replicate or compare with other studies.

4.4. Implementation of the Color-Coding System

The results indicate insufficient implementation of the color-coding system. The corresponding table shows that the recommended containers for infectious, anatomical, non-hazardous, recyclable, and pharmaceutical waste are either unavailable or used inconsistently.

This shortcoming contributes to the mixing of waste and reduces the effectiveness of the entire waste management chain (WHO, 2014; WHO, 2018). Comparable results were reported by Adu et al. (2020), who observed inconsistent application of the color-coding system in five Ghanaian hospitals, as well as by Afesi-Dei et al. (2023), who found that color-coded containers were not always used in accordance with recommendations. The issue of color-coding must

therefore be understood as a matter of equipment availability, standardization of procedures, signage, and monitoring of practices.

The difficulty appears to stem from two interrelated problems: insufficient equipment in certain facilities and the misuse of equipment when it is available.

This distinction is important for public policy. In under-equipped facilities, the priority must be to provide appropriate equipment. In facilities that are already equipped, such as Tshofa, the main challenge seems to lie more in strengthening competencies, standardizing procedures, and ensuring supervision.

However, the color-coding system used to evaluate facilities must be explicitly linked to the national or international standards adopted in the methodology.

4.5. Training and Equipment: Necessary but Insufficient

A comparative analysis of the results reveals a relatively consistent pattern: Tshofa > Lubao > Kamana for several indicators, notably training, equipment, and compliance.

However, the variations among these indicators show that the relationship is not automatic.

In Tshofa, approximately four out of five workers have received training, but compliance stands at only 55%. This suggests that the translation of knowledge into practice may be limited by several organizational factors: the consistent availability of containers, access to equipment at the point of production, workload, frequency of supervision, posting of protocols, organization of internal collection, or team accountability.

Thus, compliance should be viewed as the result of an interaction among four dimensions: staff competencies + available equipment + internal organization + supervision. This systemic approach is preferable to an interpretation that attributes non-compliance to a single factor (Caniato et al., 2015; Windfeld and Brooks, 2015). Recent literature confirms this interpretation: Ibrahim et al. (2023) identified training, guidelines or posters, and the availability of color-coded trash bins as factors associated with waste segregation. The present study adds a further dimension: the case of Tshofa shows that even with simultaneous improvements in training and equipment, a significant gap in compliance may still persist, which reinforces the hypothesis regarding the role of organization and supervision.

4.6. Health and Environmental Risks Associated with Observed Practices

The non-compliant practices identified in the facilities studied are likely to generate several categories of risks.

The mixing of infectious, sharps, pharmaceutical, and general waste potentially increases exposure for healthcare workers, waste collection staff, patients, and communities. Uncontrolled disposal practices can also pose risks to soil, water, and air quality (WHO, 2014; Windfeld and Brooks, 2015).

However, these consequences should be interpreted as potential risks documented in the literature and not as impacts directly measured by this study. The protocol did not measure soil or water contamination, nor did it measure concentrations of atmospheric pollutants. The wording of the article should therefore avoid asserting that such contamination occurred.

Uncontrolled burning or incineration warrants special attention. It can produce not only greenhouse gases but also particulate matter and other air pollutants, depending on the nature of the waste being burned. It would therefore be more rigorous to refer to risks of air and climate emissions rather than directly presenting the emissions as measured impacts (WHO, 2018).

4.7. Environmental Perceptions and Willingness to Change

The results regarding perceptions show that a significant proportion of respondents recognize the poor management of biomedical waste as an environmental problem. Furthermore, several respondents state that they would be willing to improve their practices if an appropriate system were put in place. This willingness aligns with the idea, discussed in the literature, that sustainable improvement in waste management depends not only on individual motivation but also on the creation of an institutional environment that enables staff to effectively adopt best practices (Caniato et al., 2015; Afesi-Dei et al., 2023).

This finding is interesting because it suggests that barriers to improvement are not necessarily linked solely to individual attitudes. The lack of operational mechanisms, equipment, and institutional oversight also appears to play an important role.

However, the percentages shown in the corresponding graphs must be recalculated, as some of the values presented do not correctly total 100%. Definitive interpretations of this section will therefore have to wait until the original data has been verified.

4.8. Limitations of the Study

The results of this study must be interpreted with several limitations in mind.

First, the purposeful selection of facilities and respondents limits the generalizability of the results to all health care facilities in the region.

Second, the method for calculating compliance score needs to be explained more clearly to ensure reproducibility.

Third, some of the information is based on staff reports and may be influenced by social desirability bias, even though direct observation provides a useful triangulation.

Fourth, the statistical analyses presented do not yet allow us to determine which factors are independently associated with compliance. A bivariate analysis—and, if the data permits, a multivariate analysis—would be necessary.

Finally, certain environmental risks were inferred from observed practices without direct environmental measurements. They should therefore be interpreted as plausible risks rather than quantified impacts.

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to assess compliance with biomedical waste sorting practices in the health facilities studied in the Lubao territory and to identify the main constraints likely to limit their implementation. In a rural context in Lomami Province, it provides empirical evidence useful for understanding the gaps between observed practices and the requirements for the safe management of healthcare waste.

The results highlight generally insufficient compliance with sorting practices. Reported compliance rates range from 55% in Tshofa to 40% in Lubao and 25% in Kamana, with an estimated overall average of around 40%. The main shortcomings relate to the separation of hazardous and non-hazardous waste, sorting at the point of generation, adherence to the color-coding system, the availability and use of appropriate containers, and the organization of the management chain. These findings are consistent with those reported in several African contexts, notably in Ghana and Ethiopia, where challenges related to source separation, adherence to color-coding systems, and supervision also remain significant (Adu et al., 2020; Ibrahim et al., 2023; Afesi-Dei et al., 2023).

There are significant disparities in staff training: nearly 79.5% of staff were trained in Tshofa, compared to 57.5% in Lubao and 40% in Kamana. However, the case of Tshofa shows that a high level of training and better availability of equipment do not automatically guarantee satisfactory compliance. The central finding of this research therefore aligns with the analyses by Caniato et al. (2015), Windfeld and Brooks (2015), and Hossain et al. (2011): the performance of biomedical waste management depends on an integrated system combining skills, equipment, procedures, organization, supervision, and institutional governance.

Ultimately, improving biomedical waste management in Lubao should not be viewed as a simple matter of providing trash cans or conducting one-off awareness campaigns. It should be part of a permanent institutional framework that includes regular training, equipment available at the point of generation, clearly posted sorting guidelines, a precise division of responsibilities, documented supervision, and periodic audits. Such an approach would help transform individual knowledge into sustainable and measurable practices.

In light of these findings, it is recommended that health officials and relevant authorities implement regular staff training and refresher programs; ensure a sufficient and continuous supply of compliant containers; clearly post procedures and color-coding systems at waste generation points; strengthen hygiene committees and internal accountability; and establish periodic compliance audits. These recommendations are also supported by the work of Ibrahim et al. (2023), who emphasize the importance of training, posters or guidelines, and the availability of color-coded waste bins, as well as by Afesi-Dei et al. (2023), who stress the need for a management plan and a functional oversight mechanism.

It would also be desirable to develop a standardized monitoring system to periodically measure each facility's level of compliance based on clearly defined and reproducible indicators. The development of a transparent compliance score, combined with regular inspections, would make it possible to track progress, identify priority facilities, and compare performance over time. Future research should also prioritize individual-level analyses to statistically test the factors associated with compliance and, where possible, incorporate objective environmental measures.

Finally, this study opens up an important research avenue for Lomami Province: more extensively documenting biomedical waste management in rural areas, harmonizing the standards used by healthcare facilities, and examining the links between

governance, funding, equipment availability, training, and the actual quality of waste sorting. Such an approach would help shift from a focus on identifying shortcomings to one of continuously managing quality and environmental safety in healthcare facilities.

Finally, further research should explore the determinants of compliance through appropriate statistical analyses and, where possible, incorporate objective environmental measurements to assess the actual impacts of disposal practices on soil, water, and air.

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